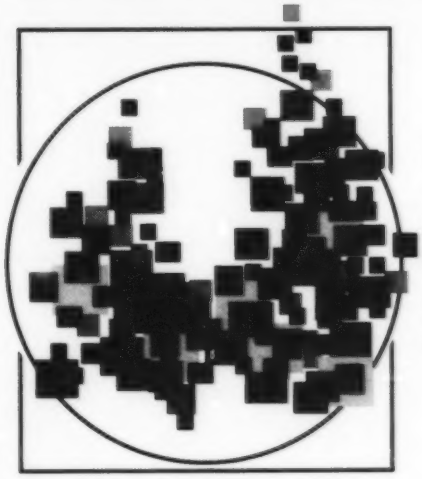

CENTRE FOR
SYSTEMS
SCIENCE

Simon Fraser University, Burnaby, B.C., Canada V5A 1S6 / (604) 291-4704

92-05400/

A User Interface Architecture Based on a Constructivist Paradigm

Chris Groeneboer and Nick Cercone

CSS-IS TR 91-04

December 1991

A User Interface Architecture Based on a Constructivist Paradigm

Chris Groeneboer and Nick Cercone
Centre for Systems Science
Simon Fraser University
Burnaby, B.C. V5A 1S6

Abstract

We present an architecture for a multi-modal, multi-application user interface. The multi-layered system consists of a set of experts, a set of associated knowledge bases, and an interface coordinator to integrate the experts. The theoretical motivation for the design is based on a constructivist paradigm. This paradigm provides a model for knowing in which knowledge is viewed as interpretive construction by an experiencing knower. A methodology emerging from and consistent with this view is then described. It consists of a hermeneutic/dialectic circle in which all those with a stake in the outcome of the inquiry are identified and their claims, concerns, and issues exposed to critique by those with different constructions. It is argued that the application of this paradigm to user interface design and evaluation is appropriate.

==========

"I don't know what you mean by 'glory,'" Alice said.

Humpty Dumpty smiled contemptuously. "Of course you don't - till I tell you. I meant 'there's a nice knock-down argument for you!' "

"But 'glory' doesn't mean 'a nice knock-down argument,' " Alice objected.

"When I use a word," Humpty Dumpty said, in a rather scornful tone, "it means just what I choose it to mean - neither more nor less."

"The question is," said Alice, "whether you can make words mean so many different things."

"The question is," said Humpty Dumpty, "which is to be master - that's all."

==========

1. Introduction

Despite Humpty Dumpty's rather remarkable discourse on semantics, this celebrated passage from Lewis Carrolls' "Through the Looking Glass" illustrates the profound role and nature of semantics. Gaining popularity during Carroll's lifetime, this nominalist notion[1] was skillfully defended by William of Occam and is now held by many contemporary logical empiricists. Although Carroll's subsequent observations which derive from his nominalism were rather quickly dispelled (that both "all" and "some" imply existence but that "no" leaves the question open), Carroll's nominalist attitude was not invalidated. Logicians simply find the concept useful, just as mathematicians might argue over the "meaning" of the term 'imaginary number'. Arguments to the contrary are useless because such words mean precisely what they are defined to mean; no more, no less.

Alternatively, if we wish to communicate accurately and effectively, we are, in a sense, under a "moral" obligation to avoid Humpty's practice of giving private meanings to commonly used words. May we make our words (or actions) "mean" whatever we choose them to mean? May we pay our words (or actions) extra, or is this the substance of propaganda? Have we an obligation to prior usage? Can we learn meaning? In one sense words are our master, or communication would be impossible. In another sense, we are the masters; otherwise there could be no poetry.

Consider the word usability. Humpty Dumpty might reserve its use for very

[1] Strictly speaking, the aspect of nominalism to which we are referring is simply that universal terms do not refer to objective existence but are nothing more than verbal utterances.

flexible systems capable of interpreting his every desire accurately (no matter how the desire is expressed) and of effectively carrying out his wishes. We all have some feeling for what the word means in a broad sense, but when we try to get a more fine-grained definition, we find that it is context-dependent. For example, we can agree that usability has to do with correctness, reliability, ease of use, convenience. But what is a convenient interface? That depends on individual preferences, how experienced the user is, what the task is, among other things. When correctness and reliability cannot be guaranteed, what compromises should be made? When are compromises tolerable or intolerable? Who should be making these decisions?

In this discussion, we present two features we believe are necessary to promote flexibility in future information systems. We present a user interface architecture for multi-modal, multi-application usage. In addition, we believe the constructivist paradigm as described usefully contributes to the design of such interfaces.

In the next section we define constructivism and describe a constructivist methodology. The application of this methodology to user interface design and evaluation is examined in section 3. Section 4 contains the discussion and presentation of a user interface architecture based on this constructivist paradigm. We record some final thoughts and observations in the final section as well as incorporate how we intend to carry out an experimental phase of design.

2. Constructivism

Operational definitions often substitute for more traditional definiendum and definiens as found in the world's leading dictionaries. This is especially true when examining concepts in the pre-paradigm or paradigm stage of formation. We avoid, in the strictest sense, any definition other than the operational definition and describe characteristic features of constructivism in this section.[2] More detailed analyses can be found in Watsalawick (1984), Fuss (1989), Belenky et al. (1986), and Guba & Lincoln (1989).

Constructivism is a way of thinking in which knowledge is viewed as interpretive construction by an experiencing knower. It differs from certain other ways of knowing in the way in which the relation between knowledge and reality is dealt with. Metaphysical realists insist that "truth" be affiliated with a notion of an objective reality independent of all experience. Knowledge is knowledge when it *matches*, or represents, or reflects, the real world. Constructivists view knowledge as "something that the organism builds up in an attempt to order the as such amorphous flow of

[2]We do not wish to enter into the constructivism/social constructionism debate. Both acknowledge the importance of cognition and of social factors. Some versions of constructivism claim cognition to be more fundamental, whereas social constructionists claim social factors to be more fundamental in the construction of knowledge.

experience by establishing repeatable experiences and relatively reliable relations between them" (von Glasersfeld 1984, p.39). Thus, the knower creates knowledge that *fits*, or orders, or organizes, the knower's interactive experiences with the world.

Von Glasersfeld (1984) uses two metaphors to describe the distinction between the match relation of metaphysical realists and the fit relation of constructivists. The search for knowledge that *matches* reality is like the search for paint to match the colour on a wall that needs repair. Alternatively, we say that a key *fits* a lock if it opens the lock. *Fitness* is a characteristic of the key, not of the lock, and there may be many different-shaped keys that open a particular lock. How well the key works depends not on finding a lock which it opens, but on it opening the way to one's goals. We view fitness as a characteristic of the interaction of key, lock, individual, and goal.

Thus the constructivist view of truth and knowledge differs from the metaphysical realists' view in that knowledge is not required to be true in an absolute sense, i.e., it is not required that knowledge match an objective, experience-independent reality. Constructivism offers no description of an absolute reality, but a model for knowledge and knowing in which cognitive organisms construct a more or less reliable world based on experience. Constructivist epistemology explores the activities, or operations, we engage in to organize the flow of experience with our environment. Knowledge is not, therefore, the result of passive receiving, but of a knower's activity. Through this process, the knower becomes an intimate part of the known.

Knowing involves the integration of rational and emotive thought, of subjective and objective strategies. Both are important in understanding how we construct knowledge. Knowledge (and truth) is contextual in that we build knowledge based on contextual experience and within a frame of reference (which is also constructed). Theories are thus models for approximating experience. These models evolve as the constructor is faced with new observations and with the constructions of others. This dialectic interaction facilitates the development of "adequate" theories. So it is important to examine basic assumptions and the conditions in which a problem is articulated, as well as the relationship between knower and the nature of thought. Consistent with this perception, question-posing and problem-posing can be used as a method of inquiry.[3]

A methodology emerging from and/or consistent with the constructivist view has variously been described as naturalistic (Lincoln & Guba, 1985), constructivistic (Guba & Lincoln, 1989), participatory (Reason & Rowan, 1981; Freire, 1970), or cooperative (Reason, 1988; Schon, 1983). Related ideas are found in the work of Winograd & Flores (1987), Norman & Draper (1987), Dasgupta (1989, 1990), and Laudan (1977).

---

[3]Compare this view with hypothetico-deductive inquiry in which the answer (hypothesis) is put forth prior to data collection. This is not to say that a hypothetico-deductive strategy is not important for exploring some problems.

The methodology described by Guba & Lincoln (1989) consists of a hermeneutic/dialectic circle in which *stakeholders* (all those with a stake in the outcome of the inquiry) are identified and their claims, concerns, and issues (CCIs) exposed to all other stakeholder groups. Constructions are critiqued by those holding different constructions. This process may iterate several times, hopefully resolving some CCIs at each iteration and converging on more sophisticated construction(s). An agenda for negotiation is devised to deal with unresolved CCIs. Representatives from each stakeholder group meet to work through the agenda. The process is hermeneutic in that the goal is to develop more sophisticated and informed constructions. It is dialectic in that it involves challenges to one's constructions by those with different constructions. Reaching consensus is not always possible (or even desirable), so the outcome may consist of multiple, joint constructions.

The success of the hermeneutic/dialectic circle depends on commitment to what Belenky et al (1986) have called *real talk*. They distinguish real *talk* and *didactic talk* where *real talk* requires careful listening to create an environment in which ideas can grow. It includes questions, argument, speculation, sharing, and exploration. *Didactic talk*, on the other hand, involves an intention to hold forth rather than share ideas. There is no attempt to arrive at new understanding. The argument as war metaphor fits this type of talk. Opponents do battle (argue) until one side wins. The distinction is one of reciprocity and cooperation vs. domination.

3. Constructivism and User Interface Design and Evaluation

As we sought to define usability, we found that usability is very much constructed knowledge based on contextual experience, which integrates rational and emotive, subjective and objective components and approximates experience. For example, multiple constructions exist as to what an interface does, what it can do, what questions can be asked and how they can be asked. Moreover, constructions about the interface and how it is used, change dynamically as the user becomes more sophisticated.

Constructions are fashioned out of personal, work, social, and cultural context. Individual users have particular likes, dislikes, work habits, task analysis and processing strategies, for example. The work environment includes a physical arrangement and an organizational arrangement for defining the work and the ways in which the work is to be accomplished. These elements of context are, of course, inextricably intertwined in such a way that they yield a unique context. However, we have observed some commonalities and do expect some general principles to emerge.

The integration of rational and emotive, subjective and objective aspects is evidenced in user replies when asked what features they want in an interface. "It depends on the particular task I'm working on, the time of day, how I'm feeling." Users

expect correctness and reliability, reasonably expeditiously. What "reasonably expeditiously" is depends on many things and varies between and within individuals.

Usability, like a constructivist theory, approximates experience. Interfaces are built with a metaphor in mind, e.g., office systems are often designed based on a desktop metaphor. As another example, CAD systems allow the user to manipulate images and quickly render what a particular design will look like.

In the following we argue for the relevance of a constructivist paradigm in human-computer interface (HCI) development. Certain points apply to the more general problem of human inquiry and other points apply specifically to HCIs. The argument takes the following form.

1. Values permeate the investigative process at many levels.

2. If the Indeterminacy Principle and the Bohr Complementarity Principle hold, then the choice of questions to be asked and the instrumentation to be applied and the values underlying these choices determine, in an important sense, the results obtained.

3. Information is power.

4. Therefore, those in a position to make such decisions are empowered whereas those excluded from the process are disempowered and disenfranchised.

5. Values and decision-making power are issues inextricably intertwined in the investigative process. In cases of human inquiry the values of the "object" of inquiry also play an influential role.

6. Therefore, a paradigm which explicitly deals with issues of values and power is appropriate for human inquiry.

It is helpful for the purposes of our discussion to refer to the *investigative process* as a process of question-exploration in a broad sense to allow for other ways of knowing. We use the term exploration instead of answering because question-answering implies expectations of a single, correct result. Such a broad definition serves to place the scientific paradigm within a framework in which it is just one of many possible paradigms. (This is also a step toward defusing the "authority" of science and legitimizing other "ways of knowing.")

The investigative process consists of posing a question or defining a problem and deciding on a paradigm within which the question/problem can be explored. Values are introduced into the process whenever choices are made. Choosing one question or

definition of a problem excludes other formulations. This is important because the articulation of a question/problem defines the focus of the exploration or examination and in this way constrains the results/solutions that will be found. Certain assumptions are made about the world, the nature of the problem, etc., when a paradigm is chosen.

Once a paradigm has been selected, values further permeate the process and influence the results in that choices must be made with regard to theoretical foundations and experimental design including instrumentation and analysis modes. Consider the wave/particle theories. Experiments can be designed in which wavelike results are obtained, and others in which particle results are obtained. The double slit experiment demonstrates particle behaviour with wavelike interference. Subjectivity is also involved in the interpretation of results and conclusions drawn. The social and cultural context in which the investigator lives and has been educated strongly influences the choices made.

These choices influence the observed state of the phenomenon under study, according to certain principles. Heisenberg's Indeterminacy (Uncertainty) Principle asserts that the actions of the investigator make certain observations possible while making certain other observations impossible. For example, the choice of a certain experimental apparatus allows determination of the mass of a particle but makes determination of that particle's velocity impossible. The Bohr Complementarity Principle asserts that the interaction between investigator and "object" influence the results obtained. So, for example, the results depend on the nature of the questions asked and the order in which they are asked as well as on any independent, objective "reality."

It has often been stated that (knowledge) information is power. If this is true, and if information resulting from an investigation is determined to an important extent by the interaction of investigator and phenomenon investigated, then it follows that those in a position to make decisons about the nature of that interaction are empowered whereas those excluded from the process are disempowered and disenfranchised. If all those who may be affected by the findings of a study do not have an opportunity to participate in the process, then the questions and concerns of certain groups will not (cannot) be addressed.

The subject-object independence assumption[4] is contraindicated even in the physical sciences in which case the object is often an inert body or substance. The focus of our examination of this influence has thus far been on the values and power of investigators (and those who commission studies). In the case of human inquiry another level of interaction comes into play.[5] The values and power of the "object" of the

[4]This assumption asserts that an observer (subject) can remain independent of the observed (object), i.e., can observe without influencing the object and vice versa.

[5]We do not intend to purport the human sciences/natural sciences dichotomy. These issues are important to the natural sciences as well.

study interact with those of the (subject) observer. Therefore, we conclude that a paradigm which explicitly deals with issues of values and power is appropriate for human inquiry.

The situation is even further complicated with another level of interaction when the "object" of inquiry concerns human-computer interaction. The thrust of the argument for the relevance of the constructivist paradigm in doing HCI development is that (1) user interfaces are value-laden, (2) usability is contextual, integrates rational and emotive, subjective and objective elements, and (3) the constructivist paradigm provides a good ontological/epistemological "fit."

Computer systems in general are value-laden. Choices must be made as to what the system can and cannot do (specifications/requirements). Values are embedded directly in code in the form of algorithmic choices with regard to how the system meets its requirements. The characteristics of a "good" program include correctness, reliability, portability, maintainability, readability, and minimum use of resources. Of course, there are usually tradeoffs: time/space tradeoffs, resource-efficiency/algorithmic-elegance tradeoffs, for example. Heuristic algorithms offer a "good" answer most of the time as opposed to a correct answer all the time for intractable problems.

That HCIs are value-laden is important because the interface controls both access to information and the way humans and computers interact. What questions can be asked and how they are posed is determined by the type of interface. A graphic interface requires that questions be posed in terms of defined graphical objects, whereas a menu-based interface requires that questions be posed in terms of items on menus presented in a certain (possibly dynamic) order. Questions posed to a natural language interface are limited by the linguistic coverage of that interface. For any given interface, there will be questions that cannot be asked. Also, interfaces integrating user views restrict access to database information depending on the type of user. For example, users doing customer billing might have access to customer information but not payroll information.

Values play a major role in the definition of usability, and the hermeneutic/dialectic circle seems a natural environment in which to develop joint construction(s). Users will have multiple constructions about what a given interface does, what it can do, the questions that can be posed, how they can be posed, etc. For example, naive and expert users have different constructions about the interface as do users assigned different user views. Also, users' constructions about the usability of an interface change, becoming more sophisticated as user and interface interact.

There are also practical reasons for using the constructivist paradigm. The goal of HCI developers is to have their systems used. Developers from the business realm wish to sell their interface products, and developers from the research realm presumably wish to have feedback about whether their systems work, are usable, etc. If end-users are not involved and their concerns not met, they will not use the system. If end-users

play an active role in design and evaluation, there is a better chance for success of the system. End-users may include managers, payroll employees, customer service representatives, etc. These people constitute groups at risk and are in a position to broaden the range of HCI development to the benefit of the hermeneutic/dialectic procedure, and in the process become mutually educated.

4. The User Interface Architecture

The conceptual-level design for our multi-modal, multi-application user interface architecture is shown in Figure 1. The architecture incorporates five layers -- user, modalities, interface proper, applications, and operating system. Requests and responses flow across layers, undergoing transformation at each layer. User requests flow down through the layers to the appropriate application System responses flow up through the layers to the user in an appropriate modality for presentation.

The interface proper (enclosed within the lightly-shaded area) translates the input request from a modality-dependent representation to an application-dependent representation. Once in this translated form, the request can be made of the appropriate application and a response solicited. The interface translates the application-dependent response to an appropriate modality-dependent representation which is then presented to the user.

The conceptual design of the interface shell reflects our efforts to deal with the portability problem. We want a system that is general enough to be utilized in many different environments, but it must also incorporate context-dependent elements in order to make the system useful and appreciated within a particular environment. For example, the modality of choice depends on many things and varies between and within user groups, and within individuals. Naive users learn to use new systems more expeditiously with natural language (Napier, Lane, Batsell, and Guadango, 1989) whereas many expert users prefer structured control to exploit speed of use. However, either group may prefer a graphical display for certain tasks, e.g., *clicking* on a region of a map to obtain information about that region. Variation within individuals alone justifies a multi-modal approach.[6]

One design goal of the architecture is to provide a shell which contains features for coordinating modalities, applications, and individual users. The layered, modular design facilitates change, such as the addition of a new application, modality, or user, or installation in a new context. Another goal is to provide user modelling to help make the system meaningful in a particular context.

The interface proper layer performs the coordinating task. It consists of a set of

[6]Variation within individuals may be due to the nature of the task being performed, familiarity with an application, "time of day," or "how someone is feeling," e.g.

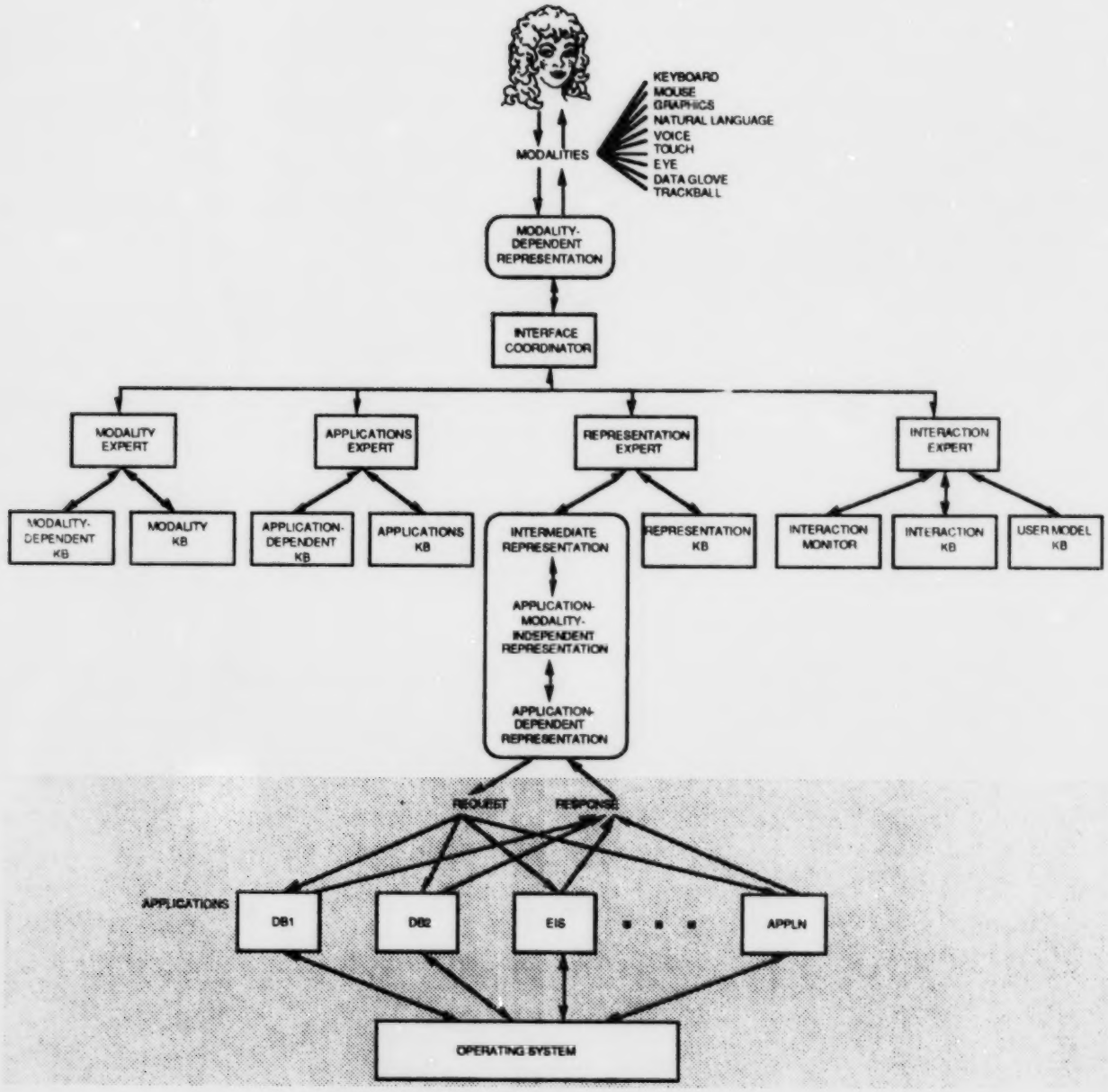

Figure 1. A multi-modal, multi-application user interface architecture.

experts -- the modality expert, the applications expert, the representation expert, the interaction expert -- and a coordinator to integrate these experts. Each expert has access to dual knowledge bases -- one knowledge base containing general information and the other knowledge base more specific information. The modality expert, for example, has access to the modality knowledge base (KB) and the modality-dependent KB. The modality KB contains information about modalities in general, e.g., the kinds of information best suited for presentation with each of the modalities. The modality-dependent KB contains knowledge about specific modalities, e.g., the natural language modality. Ideally, user and system have a choice among multiple modalities with which to interact. The expert aids in deciding which modality is appropriate for presentation of the response to the user. The coordinator integrates modality information and individual user information such as preferences in making this decision.

The applications expert accesses the applications KB and the application-dependent KB. The application KB contains general information about the applications -- about databases, executive information systems, CAD systems -- what they are, their intended use, etc. The application-dependent KB contains domain-dependent information for each application, e.g., a database scheme.

The representation expert is responsible for the mappings from one representation to another. Requests are translated from a modality-dependent representation to an intermediate representation to an application-modality-independent representation to an application-dependent representation. The reason for translation to an application-modality-independent representation is a savings in the total number of mappings required by the system. When a new application is added, the system needs only one mapping from the application-dependent representation to the application-modality independent representation as opposed to mappings to each modality. Similarly only one mapping is required for a new modality.

The intermediate representation makes the translation to the application-modality-independent representation easier. It was our experience with SystemX, a natural language interface (Cercone et al., 1990), that an intermediary representation (a logical form) facilitated translation to SQL. The representation KB contains knowledge about the mappings.

The interaction expert deals with principles and problems of human-computer interaction. It accesses the interaction KB for information regarding interaction with humans in general, and the user model KB for information regarding individual users, their preferences, familiarity with the system/modalities/applications, sublanguage, etc. The interaction monitor keeps track of the current session, e.g., user, context, focus, task.

The interface coordinator oversees the flow of requests and responses. It directs experts to make certain decisions and passes messages back and forth between experts as

required. For example, the user makes a request in natural language requiring access to a particular database. The natural language component results in multiple parses which it cannot disambiguate. The coordinator sends a message to the interaction expert requesting information about the user that might help in this situation.

Winograd & Flores (1987) suggest viewing a user interface in its context as layered like an onion. The innermost layers represent the user interface and its structure, whereas the outer layers represent the context in which the user interface is used. They claim that we need to be looking outward not inward from the object of focus and that most of us understand the tool in the context of how the system we are building gets the work done, but that we need to go beyond to the outer layers--even to social implications. We feel that cultural context also needs to be considered in designing systems of the future. It is interesting to note, e.g., the cultural differences in the way Sinclair's (1989) Hyper-Postcards system has been used.

Figure 2 gives an onion-layered conceptualization of our design. Requests and responses move across these layers, undergoing transformation at each layer. The interface is responsible for accurate translations and appropriate forms of presentation of information in the system. Appropriateness includes such characteristics as helpfulness, convenience, informativeness. For example, we often pose yes/no questions, but we really want more than "no" for an answer. Responses to questions concerning locations (of breakdowns in service, say) might best be presented as points on a map in a graphical display.

5. Discussion

We would like to stress that the architectural design presented in section 4 is a conceptual one. The goal is to capture the elements of interaction which can be generalized in a shell, and then customize, or tailor, the system to a particular context. Ideally this customization is done automatically. Obviously, the space requirements for a truly general multi-modal *and* multi-application system are great. However, we expect that larger amounts of memory at lower rates will be available in the future (User Interface Strategies panel discussion, 1990), and that designing with this in mind makes for better systems in the long run. In the meantime we plan to begin experiments with two modalities and two applications.

Multi-modal access to one application presents unique and interesting problems as does uni-modal access to multiple applications (the portability problem). A multi-modal, multi-application system must deal with all these problems. One problem is that in many cases modality and application appear inextricably intertwined, e.g., object-oriented icon-based access to databases. A possible solution is an automated, tailorable icon package for systems of the future. Graphical interfaces seem more prone to this problem than other modalities, natural language, e.g. Much domain knowledge is

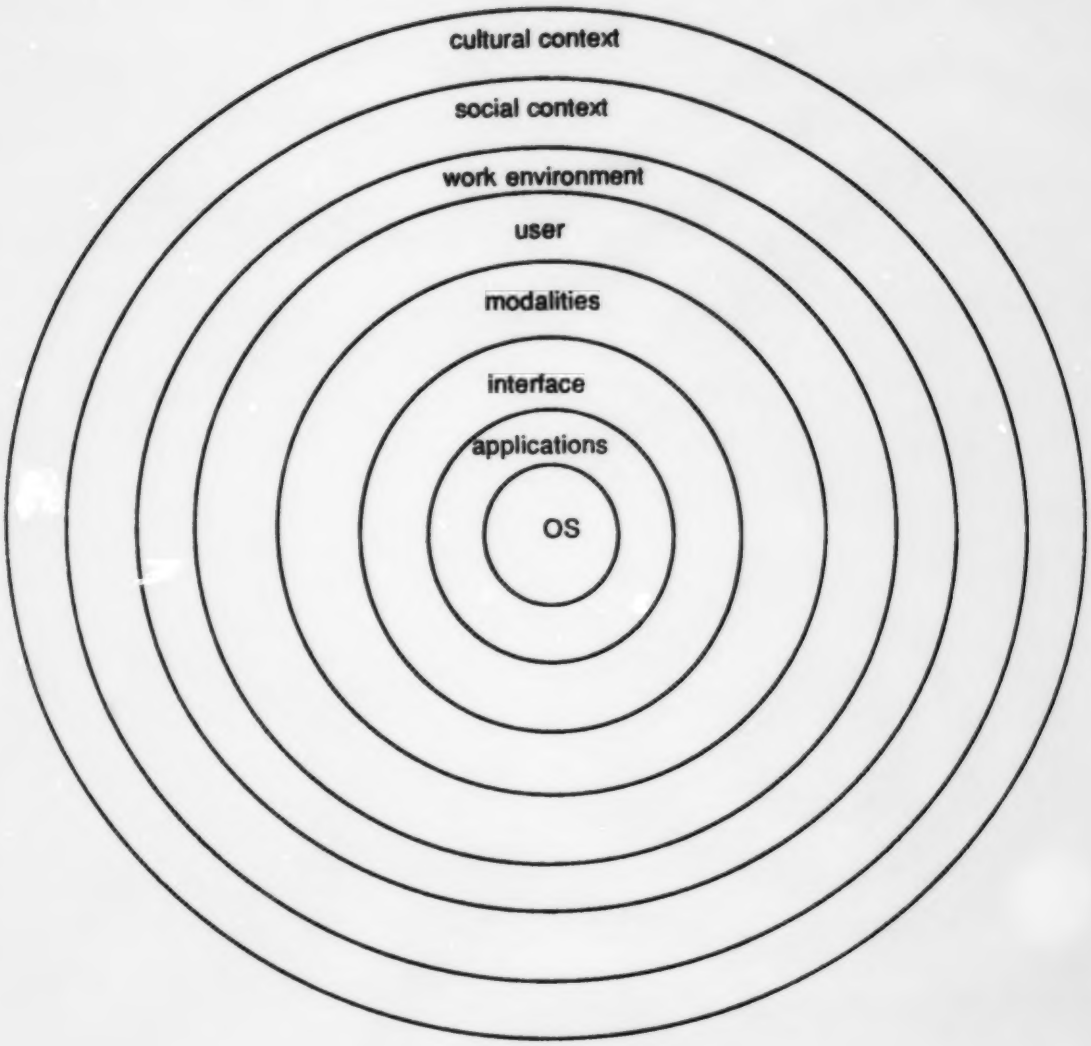

Figure 2. Layers of a User Interface System.

required even for natural language interfaces, but the portability problem has been widely investigated (Bates & Bobrow, 1983; Kaplan, 1984; Martin, Appelt, Grosz & Periera, 1985; special issue on portability of the *ACM Transactions on Office Information Systems,* 1985).

Finally, there are also problems with the practicalities of the methodology, e.g., dealing with value-pluralism and decision-making power. However, we hope we have convincingly shown that these problems exist with other methodologies and cannot be avoided.[7] The goal of the hermeneutic/dialectic process is to acknowledge value-pluralism and to deal with it explicitly right from the beginning and in an equitable fashion.

Two difficult problems discussed at length in the panel discussion on participatory design (CHI '91) were power and communication. It is difficult to establish equality of the participants because of the hierarchy of power within the work environment. The communication problem is particulary acute when participants are from different areas. They may be unaware of jargon or special meanings of words within other areas. Worse yet, the same word often has different special meanings within different areas. However, we feel that it is well worth the effort to attempt to overcome these problems and that interesting and meaningful outcomes are possible.

References

*ACM Transactions on Office Information Systems. (1985).*Special issue on transportability, 3(2).

Bates, M., and Bobrow, R. (1983). A transportable natural language interface. *Proceedings of the 6th Annual International SIGIR Conf. Res. Dev. Inf. Ret. ACM.*

Belenky, M., Clinchy, B., Goldberger, N., & Tarule, J. (1986). *Women's ways of knowing - The development of self, voice, and mind.* New York: Basic Books.

Bleier, R. (ed.). (1986). *Feminist approaches to science.* New York: Pergamon Press.

Cercone, N., Hall, G., Joseph, S., Kao, M., Luk, W., McFetridge, P., & McCalla, G. (1990). Natural Language Interfaces: Introducing SystemX. In T. Oren (ed.), *Advances in Artificial Intelligence in Software Engineering* (pp. 169-250). Greenwich, CT: JAI Press.

Dasgupta, S. (1989). Structure of design processes. In M. Yovits (ed.), *Advances in computers*

[7] It has been argued extensively that science is not value-free (see, for example, Bleier, 1986; Diener & Crandall, 1978; Easlea, 1973, 1983; Guba & Lincoln, 1989; Harding & Hintikka, 1983).

(Vol. 28). San Diego, CA: Academic Press.

Dasgupta, S. (1990). *Design theory and computer science.* Cambridge: Cambridge University Press.

Diener, E. & Crandall, R. (1978). *Ethics in social and behavioral research.* Chicago: University of Chicago Press.

Easlea, B. (1973). *Liberation and the aims of science: An essay on obstacles to the building of a beautiful world.* London: Chatto and Windus for Sussex University Press.

Easlea, B. (1983). *Fathering the unthinkable: Masculinity, scientists and the nuclear arms race.* London: Pluto Press.

Freire, P. (1970). *Pedagogy of the oppressed.* New York: Herder & Herder.

Fuss, D. (1989). *Essentially Speaking - Feminism, Nature, & Difference.* New York: Routledge.

Guba, E. & Lincoln, Y. (1989). *Fourth generation evaluation.* Newbury Park, CA: Sage.

Harding, S. & Hintikka, M. (eds.). (1983). *Discovering reality: Feminist perspectives on epistemology, metaphysics, methodology, and philosophy of science.* Dordrecht, Holland: D. Reidel.

Kaplan, S.J. (1984). Designing a portable natural language database query system. *ACM-TODS,* 9(1), pp. 1-19.

Laudan, L. (1977). *Progress and its problems: Toward a theory of scientific growth.* Berkeley: University of California Press.

Lincoln, Y. & Guba, E. (1985). *Naturalistic inquiry.* Beverley Hills, CA: Sage.

Martin, P., Appelt, D., Grosz, B. and Periera, F. (1985). TEAM: An experimental transportable natural language interface. *Database Engineering,* 8(3), pp. 10-22.

Napier, H.A., Lane, D., Batsell, R., & Guadango, N. (1989). Impact of a restricted natural language interface on ease of learning and productivity. *Communications of the ACM,* 32(10), pp. 1190-1198.

Norman, D. & Draper, S. (1987). *User centred system design.* Hillsdale, NJ: Lawrence Erlbaum.

Reason, P. (ed.). (1988). *Human inquiry in action: Developments in new paradigm research.* London: Sage.

Reason, P. & Rowan, J. (eds.). (1981). *Human inquiry: A sourcebook of new paradigm research.* New York: John Wiley.

Schon, D. (1983). *The reflective practitioner: How professionals think in action.* New York: Basic Books.

Sinclair, G. (1989). Hyper-Postcards: Linking Students Globally Through Multimedia

Communication. *Proceedings of the International Symposium on Telecommunications in Education.* Jerusalem, August 1989.

von Glasersfeld, E. (1984). An Introduction to Radical Constructivism. In P. Watzlawick (ed.), *The Invented Reality - How Do We Know What We Believe We Know? Contributions to Constructivism* (pp. 17-40). New York: Norton & Company.

Watzlawick, P. (ed.). (1984). *The Invented Reality - How Do We Know What We Believe We Know? Contributions to Constructivism.* New York: Norton & Company.

Winograd, T. & Flores, F. (1987). *Understanding computers and cognition: A new foundation for design.* Reading, MA: Addison-Wesley.

Centre for Systems Science

• Simon Fraser University established the **Centre for Systems Science** as a provincial centre for advanced study. The objective of CSS is twofold: coordinate and combine advanced systems research at SFU, and encourage application of research results within industry in order to further the technological development of British Columbia.

• CSS has assembled three research groups to streamline its efforts. The orientation of these groups is as follows: intelligent systems, microelectronics, and computer and communications systems. Because of shared research interests, this latter group merges with LCCR (**Laboratory for Computer and Communications Research**) for the publication of technical reports.

• CSS's three groups involve over 80 skilled faculty researchers principally from SFU's Schools of Engineering Science and Computing Science, but also draw substantially on Mathematics, Physics, Geography, Philosophy, Linguistics, Psychology, Communication, and Kinesiology.